2. CONCEPTUAL MODELS

A conceptual model is a visual or narrative summary that describes the important components of an ecosystem and the interactions among those components (NPS 2003c). Conceptual models also help identify the impacts of major drivers and stressors on ecosystem components (Barber 1994), and can aid in the identification of possible indicators for monitoring long-term ecosystem health. This chapter describes the conceptual modeling process undertaken by the GRYN to aid in the development of vital signs.

USING CONCEPTUAL MODELS

Conceptual models are beneficial to a monitoring program by providing the following (taken from Plumb 2002):

- An understanding of ecosystem structure, function and interconnectedness at varying temporal and/or spatial scales that enables identification of vital sign indicators for assessing ecosystem health in parks.
- An understanding of the range of natural and human-induced ecosystem variability, which helps park managers plan adaptive management programs, determine at what threshold variances these programs should be instituted, and then measure the results of the management programs to assess their value.

The GRYN used conceptual models at different points in the planning process. During Phase I, Patten and Schmitz developed a series of nested ecosystem conceptual models for each of the three network parks (see Appendix III). These models started with a simple overview model followed by a park ecosystem model. Nested submodels prepared for specific resources such as upland vegetation, water, riverine-wetlands and birds, provided a greater level of detail. These models, especially as they were being developed, were useful in communicating relevant ecological themes within the network parks during vital signs scoping meetings. These park ecosystem conceptual models were followed by a deliberate process for model development based on an over-arching template for information organization and vital signs selection discussed below.

DEVELOPING CONCEPTUAL MODELS

Conceptual models should demonstrate the strength and direction of connections among ecosystem components and the indicator chosen for monitoring (Olsen et al. 1992), as well as providing the anticipated response of the system to stressors (USDA 1999). Three general types of conceptual models can be used to depict these connections. These types include:

- Narrative conceptual models: models that describe an ecosystem through word description, mathematical or representational formula, or a combination of both.
- Tabular conceptual models: models that describe an ecosystem by presenting a two-dimensional array of related ecosystem components.
- Schematic conceptual models, which take one of the following forms:
  - Picture models, which show ecosystem function either in plot form or through diagrams
  - Box-and-arrow models, which represent ecosystems by focusing on key components and the relationships among them.
  - Input/output matrix models, which are a subset of box-and-arrow models that explicitly indicate mass and/or energy flow between ecosystem components.

After examination of the strengths and weaknesses of each type of model, the GRYN chose to prepare a literature review and narrative coupled with hierarchical box-and-arrow models to aid in vital signs selection due to the models ability to demonstrate how large-scale constraints (e.g., climate) can cascade down to small-scale, measurable endpoints (e.g., soil moisture [Allen and Hoekstra 1992; Allen and Starr 1982]) and their intuitive nature. This decision was also based on the ability of the models to provide information related to the 35 desirable vital sign characteristics, as described in Plumb (2002).

The GRYN then chose appropriate spatial and temporal scales as an overarching ecological framework on which the conceptual models could be developed. For the temporal aspect of the conceptual models, the GRYN chose to include 100 years before and after present because the majority of reliable historic data and knowledge developed for the ecosystems would be included. In addition, this time period represents the period of immediate utility for the vital signs selected. To choose the spatial scale for the models, the GRYN evaluated three methods that might server as an over arching template and allow for partitioning ecosystems into manageable components for model development. These methods included:

- Ecoregion classification (Bailey 1995, Omernick 1987), which yielded spatial scales that were too large for examining fine details associated with ecosystem monitoring.
- Fourth-level Hydrologic Units, which resulted in appropriate spatial resolution and sections that also closely aligned with existing land management boundaries.
- National Vegetation Classification Standards (NVCS) (Federal Geographic Data Committee 1997), which describes terrestrial vegetation by physiognomic classification and closely parallels terrestrial vegetation described in existing classifications.

Of these possibilities, the GRYN chose to use classes of terrestrial vegetation and created nine conceptual model themes, many of which included aggregations of closely related vegetation types (i.e., mixed conifer forests). In addition, two aquatic systems, one geothermal system and wetlands and riparian systems were chosen. Please see Table 2.1 for a list of conceptual models developed during Phase II and Appendix III for the complete collection of conceptual models developed for the GRYN parks.

TABLE 2.1 Ecosystem conceptual models developed during phase II vital signs planning.

Ecosystem Conceptual Model
Aquatic Ecosystem
Alpine-Timberline Ecosystem
Aspen Ecosystem
Dry Woodland Ecosystem
Geothermal Ecosystem
Grassland Ecosystem
Shrubland Ecosystem
Lodgepole Pine Ecosystem
Mixed Conifer Ecosystem
Ponderosa Pine Ecosystem
Whitebark Pine Ecosystem
Riparian/Riverine Ecosystem
Wetland Ecosystem

During development of the conceptual models, the GRYN proposed the following methods for maintaining uniformity:

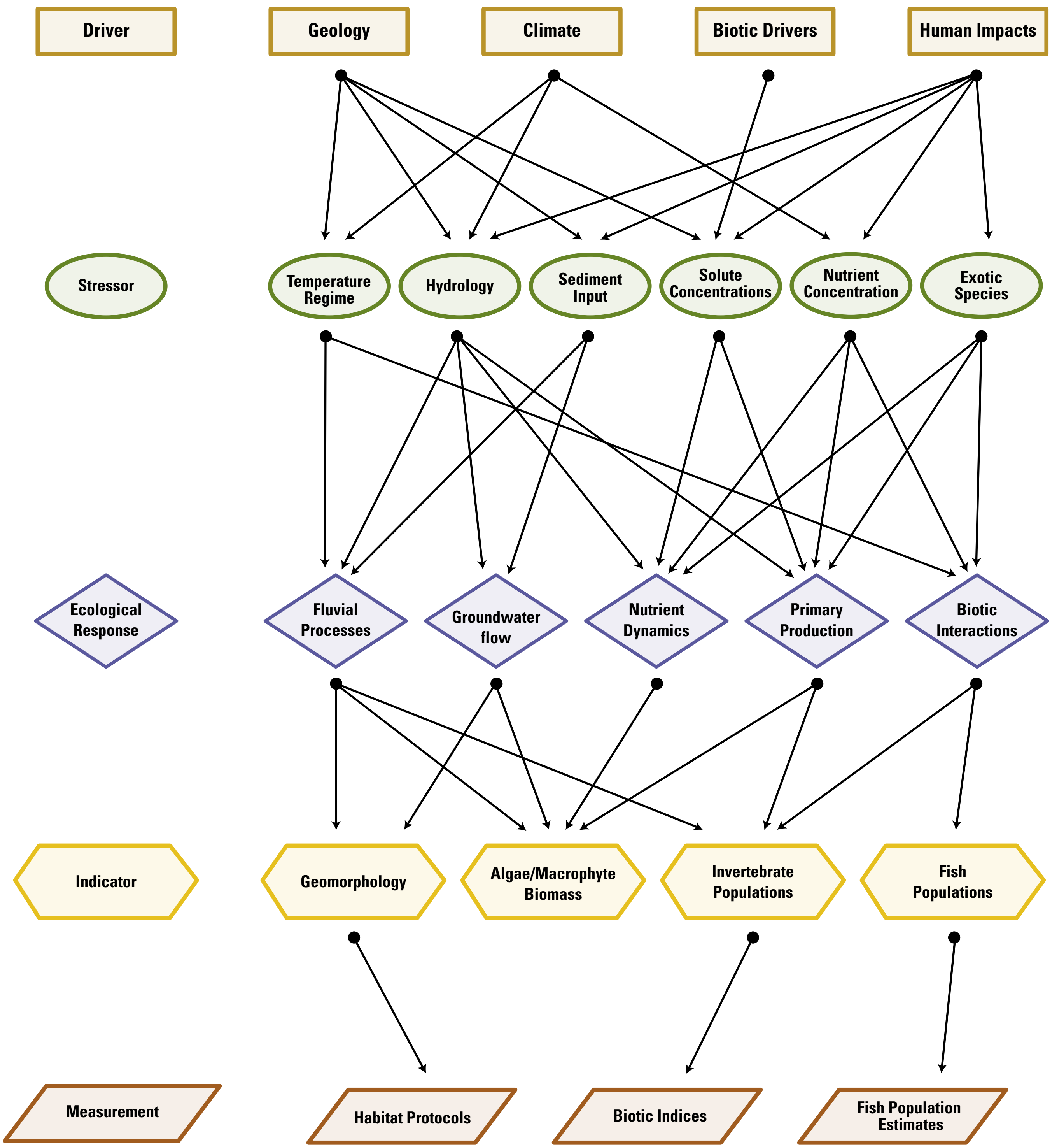
- The model should be based on a review of the relevant literature in the subject area.
- The model should identify specific resources that are vulnerable to natural and anthropogenic disturbances, primary drivers and stressors on ecosystem integrity, and ecosystem response to the drivers and stressors.
- The model should identify potential indicators for assessing ecosystem health and possible measurements of these indicators.

An example of an aquatic conceptual ecological model developed for the GRYN is shown in Figure 2.1. This model depicts drivers in the riverine ecosystem, which include abiotic processes, such as climate, as well as biotic functions, such as human impacts. The model then shows the connection between these drivers and stressors, such as exotic species. From this point, the model shows how the ecosystem responds to these stressors and how that response can lead to the identification of indicators and their measures (such as the indicator invertebrate populations and the biotic index measurement). Thus, the conceptual models can identify drivers, stressors, response variables, indicators and measurements of these indicators. Table 2.2 lists seven stressor and response variables that were recommended as vital sign indicators in the aquatic ecosystem model. Definitions of model components are described in Figure 2.1. For more information, refer to Appendix III which includes the complete conceptual model chapter which has 32 individual ecosystem models and ecosystem submodels. The use of conceptual models increases understanding of the interconnectedness of ecosystem components and helped the GRYN identify information-rich indicators. These indicators were later evaluated and ranked against a set of criteria; this planning step and outcome are described in Chapter 3.

CONCEPTUAL MODELING AMONG VITAL SIGNS

While the conceptual modeling method was first introduced in the I&M program as a method for selecting vital signs that provide a wealth of information on the state of the ecosystem, the GRYN has continued to use conceptual models to demonstrate the ecological connections among its chosen vital signs. These conceptual models help to tie sometimes disparate vital signs together and to demonstrate the way in which information from many vital signs may be tied together to give a complete picture of the state of the ecosystems encompassed by the GRYN parks.

Figure 2.2 shows a conceptual model that relates whitebark pine to other



assessing ecosystem health (refer to Appendix III). Drivers are major, naturally occurring, forces of change (can be anthropogenic) and operate on national or regional levels. Stressors are physical, chemical, or biological perturbations to a system that operate on more localized levels than drivers. Ecological effects are the physical, chemical, biological or functional responses of ecosystem attributes to drivers and stressors. Indicators are an information-rich subset of attributes providing insight into the quality, health or integrity of the larger ecological system to which they belong (Noon 2002). Measurements are the specific variables used to quality the condition or state of an attribute or indicator.

TABLE 2.2 Aquatic indicators recommended by the riverine conceptual model author (adapted from Plumb et al. 2003). See Appendix III for the riverine and lake ecosystem conceptual models and recommended aquatic indicators. After the conceptual models were complete, these indicators or candidate vital signs were evaluated and ranked by a panel of experts at the GRYN Vital Signs Workshop. The workshop is described in Chapter 3 and in detail in Appendix V.

Candidate Vital Sign	Justification
Geomorphology	Riparian vegetation not only responds to changing channel geomorphology but plays a role in its formation. Any change in channel geomorphology will consequently alter the amount and distribution of the riparian community. Thus, channel geomorphological metrics may be a useful indicator of the condition of riverine and riparian systems.
Invertebrate Populations	Stream invertebrate assemblages may change in response to exotic species, sedimentation, nutrient load or predator population change. Stream invertebrates are often used as measures of water quality (Karr 1999) and are the current approach used by the state of Wyoming for water quality analyses (King 1993). They are sensitive indicators of change and they can integrate physical stressors that might otherwise be difficult to measure, and these changes can relate to changes in ecosystem function (Wallace et al. 1996). Long term monitoring of invertebrates may be able to detect change in response to exotic mud snails, and new, unforeseen invasions.
Fish Populations	Exotic lake trout and whirling disease can potentially lower densities of native Yellowstone cutthroat trout in Yellowstone Lake; these effects may cascade to streams and predators outside of the lake (Stapp and Hayward 2002).
Algae/Macrophyte Biomass	Increased nutrients or changes to the food web (e.g. Carpenter et al. 1985) may change algal biomass, water clarity and species composition. Research in Yellowstone Lakes has shown that diatom species compositions predictably respond to slight changes nutrients according to their physiology (Interlandi et al. 1999), and these changes in assemblages may be sensitive indicators to nutrient inputs and associated climate change (Kilham et al. 1996). Algal species in high-elevation lakes can also signal changes in nutrient concentrations (Wolfe et al. 2001).
Temperature Regime	Global climate change may increase temperatures of lakes and streams which may alter animal habitat and interactions. Additionally, geologic change (e.g earthquake in Firehole River basin) may alter groundwater inputs with corresponding temperature changes in rivers. Measurement of temperature may be able to detect these changes which can be linked to any biological changes.
Hydrology	Hydrology of lakes and rivers in the GRYN can change from direct human modification (e.g. impoundments, water abstraction) or via changes in climate (Meyer et al. 1999). This monitoring is already occurring for several of the rivers in GRYN, e.g. Snake, Bighorn, Madison, Yellowstone and two of the lakes, Jackson and Bighorn.
Nutrient Concentration	Nitrogen concentrations lead to eutrophication thus increasing primary production, changing biotic assemblages and lowering water clarity (Smith 1998). Stream monitoring can detect long-term trends in deposition (Likens et al. 1996) and may provide a means to detect watershed-level response to N additions (Williams et al. 1996).

relevant vital signs chosen for monitoring by the Greater Yellowstone Network. This model is not meant to be a complete picture of all influences on the whitebark pine community; rather, its purpose is to highlight how whitebark pine fits into the larger picture of the vital signs program and how other vital signs may be connected to the whitebark pine community, thus influencing the monitoring of those vital signs. These types of models can be helpful in identifying important partnerships with cooperating agencies that are already involved in monitoring in the GRYN parks, as discussed in Chapter 1. Complete, detailed information on the ecological connections among the vital signs, such as those contained in this conceptual model, are included in the individual vital signs monitoring protocols.

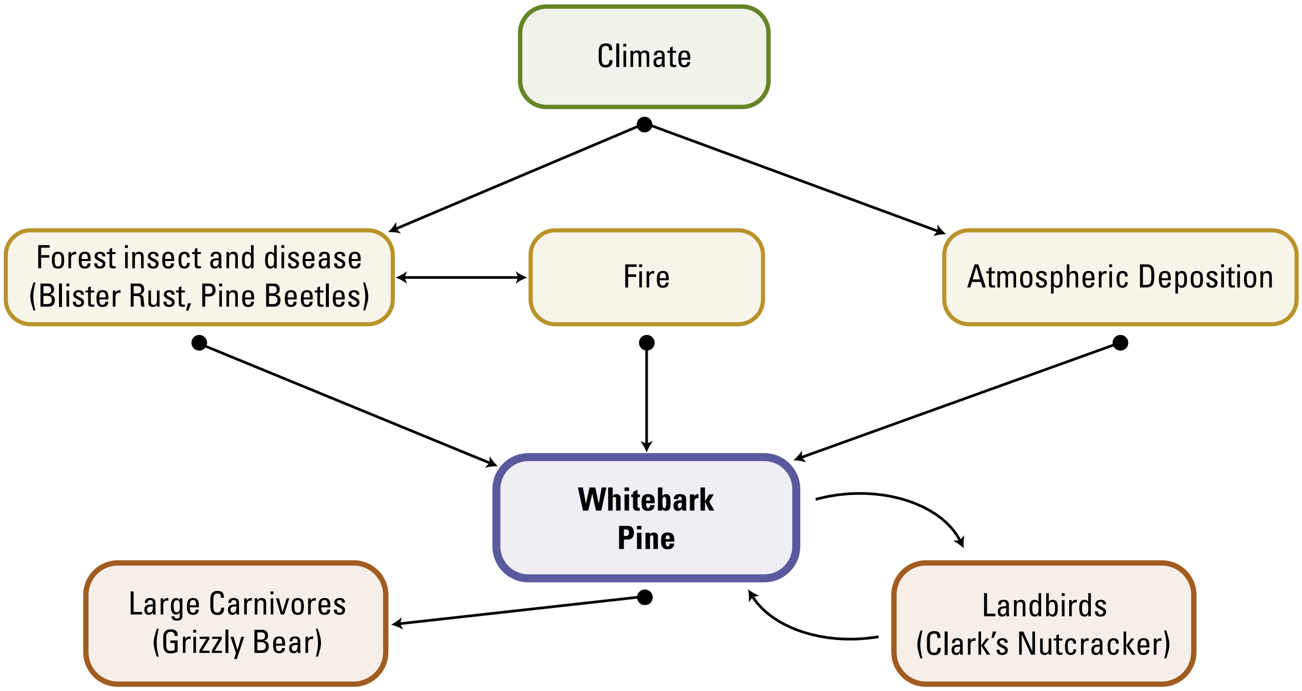


FIGURE 2.2 Whitebark pine vital signs conceptual model.